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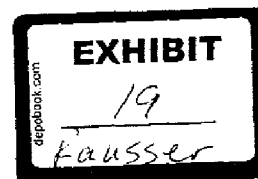
Does the Measurement of Environmental Quality Affect Implicit Prices Estimated from Hedonic Models?

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ABSTRACT. *Hedonic property value models are often used to derive point estimates for identifying the relationship between environmental quality and property prices. The measurement of the environmental quality variable is often selected based on convenience, but variables reflecting different perceptions about environmental quality may result in implicit prices that vary substantially. This case study derives implicit prices for nine measures of water clarity using hedonic property value models of lakefront properties in Maine. Results show that water clarity variables based on different perceptions may result in differences in implicit prices large enough to potentially affect policy decisions. (JEL Q25)*

I. INTRODUCTION

Since the enactment of the Clean Water Act and the Clean Air Act, a number of hedonic studies have estimated implicit prices for the effect of pollution on property values. Some studies have used single environmental variables in hedonic-price equations (Ridker and Henning 1967; Anderson and Crocker 1971; Wilman 1981; Murdoch and Thayer 1988) and other studies have used multiple environmental variables when multiple contaminants are present in the affected housing market (Brookshire et al. 1981; Brashares 1985; Epp and Al-Ani 1979; Feenberg and Mills 1980). The selection of environmental variables and the specification of these variables in hedonic-price equations are fundamental issues because these subjective choices by the investigator can affect the significance and magnitude of implicit prices. Measures of contamination levels are typically provided by natural scientists, and these variables are used as proxies of buyers and sellers perceptions of environmental quality. If these proxy variables measure perceptions with error, an error-in-variables problem is introduced that leads to biased implicit prices

(Atkinson and Crocker 1987; Graves et al. 1988; Greene 1990). Others have examined the effects of different functional specifications of hedonic-price equations, often using Box-Cox estimation (Dinan and Miranowski 1989; Parsons and Wu 1991; Lansford and Jones 1993; Graves et al. 1988). However, little attention has been given to the selection of environmental variables that appropriately reflect buyers' and sellers' perceptions of environmental quality.

It appears that most hedonic studies are conducted using whatever empirical measure(s) of environmental quality is (are) available as the environmental variable(s), and these measures of environmental quality may not represent public perception of water quality. Consequently, an issue that appears to have been overlooked in the literature is the appropriate selection of an environmental variable to include in the hedonic-price equation. Suppose, for simplicity, the issue is water quality and there is only one contaminant. Issues of measurement error and functional specification aside, a question arises as to whether the effects of pollution on property values are caused by future expectations of water quality based on long-term or short-term changes in water quality, or current water quality conditions, or some combination of these three variables. The concern here is

different from an error-in-variables problem, where the question pertains to whether historical and current water quality are measured with error. The issue is: Which of these variables, or what combination of these variables, do people consider when arms-length transactions occur? It is necessary to understand how the public perceives water quality because the selection of different variables representing the same type of contamination is also a subjective decision by the investigator that can affect the significance and magnitudes of implicit prices.

This paper examines the effects of alternative environmental variables on implicit prices using the issue of eutrophication resulting from nonpoint-source pollution in Maine lakes. This application presents a unique opportunity because eutrophication is the only type of water quality problem in the lakes studied, and the level of eutrophication is not constant through time.[1] As with the hypothetical example in the preceding paragraph, the question centers on the use of long-term changes, short-term changes, or current water quality in the hedonic-price equation. Water clarity is the physical manifestation of eutrophication, so measures of water clarity are used as the environmental variable. Historical records of water clarity are available from the Maine Department of Environmental Protection (MDEP) for the lakes included in the study. Water clarity is measured by lowering a black-and-white Secchi disk into the water. The point at which the disk disappears from sight is a measure of water clarity.

A telephone survey was conducted with a sample of property purchasers to investigate what measures of water clarity they considered when buying their properties. Based on the results of this survey, nine different water-clarity variables were constructed using the Secchi disk data.

II. MEASUREMENT OF THE ENVIRONMENTAL VARIABLE

Hedonic property value models have been used to value everything from earthquake risk (Brookshire et al. 1988; Murdoch, Singh, and Thayer 1993) to countryside attributes

(Garrod and Willis 1992). The most common environmental application has been the estimation of the effect of air pollution on property values. The air pollution variable has been expressed as a mean value (Anderson and Crocker 1971; Ridker and Henning 1967), on a scale (Brookshire et al. 1981; Brucato, Murdoch, and Thayer 1990), and as a probability measure, such as the level of visibility that may be achieved at any particular time (Murdoch and Thayer 1988). Although these individual studies use different air quality variables, they do not examine how these variables reflect people's perceptions about air pollution. Different environmental-quality variables may be constructed from one physical-quality measure based on different assumptions about perceptions of quality, and how it enters into the property-purchasing decision. The way the environmental variable is constructed could influence the estimated implicit prices.

The same can be said of hedonic studies of water quality. A variety of indicators have been used to represent water quality. Ratings of water quality may come closest to reflecting people's perceptions, but are difficult for lake managers to use because they are difficult to link to physical changes in lake water quality. David (1968) used a subjective rating of poor, moderate, or good assigned by a member of the Wisconsin Department of Conservation to model water quality in Wisconsin lakes. Young and Teti (1984) developed a water-quality variable from a survey that ranked various locations inside and outside of St. Albans Bay, Vermont, by scenic beauty rather than physical measurements of water quality. Although this variable indicates the relative aesthetic quality of properties, it does not separate the value of water quality from other factors that contribute to scenic beauty.

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[1] Maine lakes are generally not affected by fecal coliform, chemical contaminants, or weed growth, and this is particularly true for the lakes included in the study. Subsequent to the period for which housing sales data were collected, widespread mercury contamination of fish tissue was found in Maine lakes. Because mercury contamination appears to affect all lakes, this contaminant would not be expected to cause variation in property prices across lakes.

Physical measures of water quality may be more useful to lake managers, but do not always represent recognizable levels of quality to people. Feenberg and Mills (1980) examined the correlation between 13 different physical measures of water quality and property prices. They found that oil and turbidity, physical measures that are observable to people, had the strongest correlations with property prices. In addition, Brashares (1985) estimated the value of lake water quality for 78 lakes in southeast Michigan using 39 objective measures reflecting various aspects of water quality. For instance, summer turbidity levels, chlorophyll concentrations, suspended solids, and dissolved oxygen were used, all indicators of the productivity of the lake, which translate into water clarity. The only physical measures of water quality significantly correlated with house price were turbidity and fecal coliform levels. Turbidity is an observable physical lake characteristic and coliform levels must be reported to prospective property purchasers. The evidence from these studies lends support to the notion that water quality characteristics that are not observable to sellers and buyers are not likely to be capitalized into purchase prices (Brashares 1985).

While the studies cited above investigated different aspects of water quality, (e.g., turbidity and fecal coliform), they did not consider how different constructs of individual variables, based on different assumptions about people's perceptions of water quality, affect estimated implicit prices. This issue is important because it is logical to think historical water quality conditions may cause some stickiness in house prices that would not be captured by a variable that only reflects conditions at the time of purchase. Purchasers' expectations about future conditions could also be important for sales where purchasers are likely to own the property for years. Future water quality affects enjoyment during ownership and the resale value of the property. In addition, there are different ways of portraying historical and current quality to produce indicators of future quality. Secchi disk measures of water clarity used in this study are objective measures of lake-water clarity, that are observable to people. The

Secchi disk data are used to create different variables representing long-term and short-term changes in clarity and current water-clarity conditions that provide the basis for future expectations.

III. APPLICATION

Maine is known for clear, high-quality lakes, but organic enrichment from nonpoint-source pollution threatens lake-water quality (Maine Department of Environmental Protection 1990). Eutrophication is the general symptom of increased nutrient loading, which results in increased photosynthetic productivity, primarily in the form of algal growth. Excess-algal growth decreases the recreational and aesthetic benefits of the lake, which should be reflected in people's decision to purchase property and the price paid for property.

Twenty-two Maine lakes were selected for the study in consultation with representatives from the Maine Department of Environmental Protection (James 1995; Michael, Boyle, and Bouchard 1996). These lakes comprise three separate market groups (Table 1).[2] These markets were designated based on conversations with realtors and property owners. Maine, being quite rural, defines regions of the state by urban centers (e.g., Portland, Auburn, Augusta), because these are the places that people travel to for shopping or work. The Northern Maine group is 200 miles from the other groups and is located in a very rural, agricultural region of the state. The Lewiston/Auburn and the Augusta/Waterville groups are in south central Maine. These groups define lakes within close proximity to each other. The Lewiston/Auburn area contains a small group of lakes that have been developed for many years. The Augusta/Waterville lakes encompass the Belgrade and China Lakes region. This group provides a broader range of lakes from those developed with year-round residential homes

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[2] Two other lake groups were considered for inclusion in the study. One group was excluded because communities did not maintain sufficient data on property characteristics to estimate a hedonic-price equation and the other was excluded because of a lack of variability in water clarity across lakes.

TABLE 1

MAINE LAKES SELECTED FOR THE STUDY

	Market Area	Lakes
Group 1	Lewiston/Auburn	Sabattus Lake Taylor Pond Thompson Lake Tripp Pond
Group 2	Augusta/Waterville	Androscoggin Lake Anabessacook Lake Cobbosecontee Lake Echo Lake Maranacook Lake Togus Pond China Lake East Pond Great Pond Messalonskee Lake North Pond Threemile Pond Webber Pond
Group 3	Northern Maine	Cross Lake Eagle Lake Long Lake Madawaska Lake Square Lake

to lakes known nationally for recreation. We used a Chow test to evaluate whether or not these groups were indeed separate markets and concluded that they could not be pooled (F statistics ranged from 7.7 to 11.6 across the nine models, critical $F = 1.97$). Each group of lakes provides a range of minimum clarity measurements from above four meters to two meters or less. Minimum clarity occurs during the summer months when the lake is most productive.

Maine Department of Environmental Protection employees and volunteers have taken Secchi disk readings of water clarity for a number of Maine lakes from May to October since the late 1970s. Most of the lakes had readings taken every two weeks. Clear lakes that were not experiencing problems with algae blooms were not monitored as closely, so some of the Secchi disk measurements were missing for particular years. Because these clear lakes change very little from year to year, the closest measurements in time were assumed to provide an adequate proxy for the missing data. These Secchi disk readings

provide the raw data for the construction of the water-clarity variables in the hedonic models.

IV. CONCEPTUAL FRAMEWORK

Lakefront properties can be viewed as heterogeneous, because they have a number of different characteristics that make up the good and are differentiated by the quantity and quality of these characteristics. If consumers have a choice in the quantity and quality of a market good's characteristics, then the value of a nonmarket characteristic such as water clarity can be observed through consumers' purchases in the market. Therefore, we would expect changes in clarity to result in changes in the overall value of the property (Lancaster 1966; Rosen 1974; Palmquist 1991; Freeman 1993). If two lakefront houses are exactly the same and only differ by the level of water clarity, the price for the differential between the two properties would be the marginal implicit price for the different levels of water clarity. Most comparisons are not this simple, and a hedonic model is used to control for the property attributes when measuring the marginal effect of water clarity on the overall price of the good.

The hedonic-price function is developed from the interaction of producers and consumers in the market for housing. A differentiated product such as a property can be represented by a vector of its characteristics $Z = (z_1, z_2, \ldots, z_n)$. The price of a property is a function of its characteristics, which is the hedonic-price function $P = P(Z)$. This function expresses a price schedule representing an envelope of bid and offer functions in the marketplace. Consumers maximize utility, max $U = U(X, z_1, z_2, \ldots, z_n)$, by choosing a vector of characteristics of the differentiated good (Z) and a composite of all other goods (X), subject to a budget constraint $Y = P_x X + P_z(z_1, z_2, \ldots, z_n)$ (Rosen 1974; Palmquist 1991; Freeman 1993). The focus here is on what measure of the z_i for water clarity enters the hedonic-price function $[P_z (.)]$.

The general form for the hedonic-price equation for this study expresses the sale price as a function of property characteris-

tics: $PRICE = f(S, L, WC)$, where $PRICE$ is the sale price of the property, S is a vector of structural characteristics, L is a vector of locational attributes, and WC is water clarity. The specification of the hedonic equation can have a significant impact on the estimates of the coefficients of the environmental variables, yet economic theory does not generate a single specification that is correct (Rosen 1974; Freeman 1979; Halvorsen and Polla-kowski 1981; Palmquist 1991). Structural characteristics and locational attributes used in housing models have been fairly well established in the literature, but still must be tailored to the individual housing market(s) being investigated and the availability of property data.

A linear functional form is usually re-jected because it produces constant attribute prices (Anderson and Bishop 1986). It is typ-ically assumed that consumers are willing to pay more for one unit of improvement at lower levels of environmental quality than at higher levels of environmental quality. In ad-dition, in the current application, there is evi-dence that visual perceptions of water clarity are more refined at lower levels of clarity than at higher levels of clarity (Smeltzer and Heiskary 1990). In other words, a one-meter improvement in clarity in a murky lake is more noticeable and produces a greater change in price than a one-meter improve-ment in a clear lake. Therefore, the relation-ship between price and water clarity would be diminishing. As a result, the semilog func-tional form is used for the water-clarity vari-able. The remaining property variables are entered linearly.[3]

Selection of Structural and Locational Variables

In choosing structural characteristics to in-clude in the hedonic model, it is important to choose variables that indicate the size and quality of the properties. Particular attention should be given to the inclusion of variables that, if excluded, may lead to an omitted rele-vant-variable bias in the estimate of the im-plicit price of interest, water clarity. Struc-tural variables were selected based on the literature, data availability, and the charac-teristics of the properties in our sample (Ta-

TABLE 2

STRUCTURAL AND LOCATIONAL VARIABLES

Variable	Description
Structural	
STORY	1 = more than one story
LVAREA	square feet of living area
FIRE	number of fireplaces
HEAT	1 = heated
ELHEAT	1 = electric heat
BSMNT	1 = basement
DECK	1 = deck and/or porch
PLUMB	1 = indoor plumbing
FRONT	foot frontage on the lake
SEPTIC	1 = septic system or town septic
GARAGE	1 = garage
LOTSZ	lot size in acres
Locational	
RDPUB	1 = public road
DNSTY	lots/1,000 feet of lake frontage
TAXRT	mil rate for the year the property was sold
DIST	distance to the nearest large town center
LKAREA	surface area of the lake

ble 2). The presence of or increase in size of any of these variables, with one exception, would increase the value of a house, so the coefficients should be positive. The excep-tion is electric heat, which is more costly than other heat sources in Maine.

The land that the structures are located on affects the value of a property. In fact, theo-retically, hedonic models look at the price differential between pieces of land. The

[3] A number of studies have used the flexible Box-Cox form to allow functional forms to be determined by the data. This form of flexibility is not always appro-priate when the goal of the study is to estimate the mar-ginal impact price for an environmental amenity. If *a priori* evidence suggests that the function is concave, indicating diminishing marginal value for the amenity, it would not be appropriate to use estimates from Box-Cox that may suggest a linear function fits the data best. Lambda is estimated based on all of the property vari-ables in the model. Therefore, structural characteristics are the most influential, yet lambda is applied to the environmental variable (Palmquist 1991). Using a best-fit criterion to choose the functional form does not nec-essarily lead to more accurate estimates of characteristic prices (Cassel and Mendelsohn 1985). Therefore, an as-sumed functional form is used to estimate the hedonic equation.

value of environmental quality is captured in the price of the land, not the structures situated on the land (Freeman 1993). Because much of the land is sold with improvements, characteristics of structures need to be controlled for in the estimation. The only land characteristics available from the property records are the size of the lot and feet frontage on the water and on the road (not included in the model).

Locational attributes or neighborhood characteristics are included in hedonic models to control for local amenities, which may contribute to the value of a property. Many of the attributes included in urban studies, such as crime rate, ethnic and age distribution, and quality of school systems, are not appropriate in the case of rural, recreational properties. Consequently, we include characteristics that buyers looking for recreational property might consider (Table 2).

Measurements of Water Clarity

To gain a better understanding of how water clarity was considered in people's property-purchasing decisions, a telephone survey was conducted. The survey was administered to a sample of property owners from the data set. At least one property purchaser on each lake was randomly selected, providing a sample of 99 property owners. The goal of the survey was to find out how familiar purchasers were with the lake and its water clarity before they bought the property, the type of information that the purchasers obtained about lake water clarity, and how purchasers used this information when making their purchasing decisions. The results of the survey provide information to consider the validity of the assumptions underlying the various water clarity measurements used in the hedonic regression.

Of the 99 properties randomly selected for the survey, 27 were ineligible for the survey. Specifically, 15 were eliminated because of an unlisted number or incorrect address, and 12 were eliminated because they had owned property on the lake for many years or had purchased property from family members. Of those respondents eligible for the survey, 20 were eliminated because they could not be reached. The effective response rate was 72%. Of the 52 respondents, 11 were from out of state and 41 resided in Maine.

The survey indicates that many of the respondents were very familiar with the lake and its water clarity before they purchased the property. Over half of the respondents (56%) had visited the lake for recreational purposes before purchasing the property, with 69% of these individuals visiting many times over a number of years. Most of the respondents (93%), who had visited in the past, had visited during the summer months.

The survey revealed that lake-water clarity was the second most important lake characteristic to property purchasers (62% reporting that it is very important), with the overall scenic beauty of the lake being the most important characteristic (71% reporting very important). Other characteristics, including shoreline characteristics, fishing, size of the lake, and depth of the lake were less important than scenic beauty and water clarity (less than 30% of respondents felt they were very important). A majority of the property purchasers (62%) said that they specifically looked at the current lake water clarity before purchasing the property, 56% noticed or inquired about how the lake's water clarity changes over the summer months, and 48% sought information about the past lake water clarity before purchasing the property.

Fifty-four percent of the respondents said they were influenced by water clarity in their decision to purchase property, supporting the assumption that water clarity is an attribute of properties for which there is an implicit market. Sixty-eight percent of those who were influenced by water clarity said that it influenced both the price they paid for the property and the lake on which they chose to purchase property. Twenty-nine percent said that it only influenced the lake on which they chose to purchase property, and 4% said that water clarity only influenced the price that they paid, not the lake on which they chose to purchase property. Of the 54% that said water clarity influenced their purchase decision, 43% said they based their purchase decision on the history of water clarity in the lake, 25% said they based their decision on the current water clarity alone, and 21% said

that they considered both the current and the historical water clarity. This suggests that not all people consider the same water clarity variable when making housing transactions, which is an implicit assumption when only one variable is included in the hedonic-price equation.

Property owners' perceptions of minimum water clarity, relative to the actual minimum clarity measurements for the lake, were somewhat consistent with the Secchi disk measurements of water clarity. Respondents were asked to rate the clarity of water in their lake at its worst using a scale of 0 to 8, where 0 is no visibility and 8 is crystal clear. The 0-to-8 scale was selected because clarity can range from none (0) to eight meters in Maine lakes. The correlation between the actual minimum water clarity and the respondent's rating of clarity was significant using Pearson's correlation coefficient ($r = 0.44$, $a = 0.01$). This is suggestive evidence that people's perceptions are consistent with the minimum clarity conditions on the lakes.

The results of the survey suggest that there is an implicit market for water clarity in Maine lakes. People recognize, and can describe, minimum levels of water clarity occurring in lakes. The survey also suggests that although respondents were most familiar with the current water clarity of their lake, the historical water clarity was also important to them in their purchase decision. In addition, respondents either noticed or inquired about the change in clarity that occurs during the summer months. Thus, people may respond more to the changes in clarity that occur rather than the absolute minimum clarity. Although data are not available about future water clarity on these lakes, historical, current and changes in water clarity over time may be influencing purchasers' perceptions about future water clarity and their decision to purchase property.

In summary, there are a number of water clarity issues that purchasers and sellers might consider when exchanging a lakefront property. These issues include expectations of future water clarity, current water clarity, historical water clarity, and the change in water clarity over the summer months. Any one or combination of these measures of water

clarity may be considered by parties to the sale. While expectations of future water clarity may be an important consideration, specific data on these expectations are not available. We assume that past and current water clarity will act as proxies for future expectations. The variables specified below are designed to reflect possible measures of water clarity that may reflect people's perceptions of the current water clarity conditions and their expectations about future conditions (Table 3).

Current water clarity. The first group of water clarity variables assumes that people base their purchasing decision on the minimum clarity of the lake at the time of the sale. The survey indicates that most people had seen the lake before purchasing the property and were familiar with the current level of clarity in the lake. Therefore, we used a measure of the minimum clarity for the year the property was sold (CMIN). In addition, we use the minimum clarity measurement for the year previous to the sale (PMIN). For sales that occur early in the year, the previous season's algae bloom may have the most significant effect on sale prices. A better measure, perhaps, would be water clarity at the time the purchaser observed the lake. Unfortunately, the only data available are the dates the sales close.

Historical water clarity. The second category of water clarity variables represents historical water clarity. The survey indicates that many respondents sought information about the history of water clarity in the lake and that historical water clarity influenced their purchasing decision. To capture historical water clarity, we used the average of the minimum water clarity measures for the summer months for the ten years prior to the sale year (HMIN). HMIN represents the lag that may occur in consumers' views of the general quality of the lake water, thereby causing stickiness in property prices. When a lake that has always been clear begins to exhibit algae blooms, people may still think of the lake as clear and free from water clarity problems. In reverse, a lake with improving water clarity may still be thought of as a lake with problems. The marginal value of HMIN has a less convenient application for policy

TABLE 3
DESCRIPTION OF WATER CLARITY MEASUREMENTS

Variable	Description	Expected Sign
Current Water Clarity		
CMIN	Minimum water clarity for year property was sold.	+
PMIN	Minimum water clarity for year previous to sale.	+
Historical Water Clarity		
HMIN	Ten-year average of minimum water clarity.	+
Current and Historical Water Clarity		
CMIN * HMIN	Interaction term between the current and historical minimum water clarity.	+
CMIN * HMIN±	Interaction term (adjusted for degrading = neg. value, and improving = pos. value).	+
CMIN-HMIN	Difference between the current minimum water clarity and the historical minimum clarity.	Indeterminate
HMIN+	1 = Improving water quality trend, 0 otherwise.	Indeterminate
HMIN−	1 = Degrading water quality trend, 0 otherwise.	Indeterminate
Seasonal Change in Water Clarity		
CMAX/CMIN	Maximum water clarity for year property was sold divided by the current minimum clarity.	−
CMAX/CMIN%	Percent change in clarity over the summer months.	−

purposes as it is not possible to change the historical level of water clarity. Another problem with this variable is that two lakes could have different trends (increasing or decreasing in water clarity), yet have the same historical average and consequently the same implicit price.

Current and historical water clarity. The results of the survey indicate that purchasers were most familiar with the current water clarity, but the historical water clarity had a greater influence on their decision to purchase property. Therefore, both current and historical clarity could be important variables to include in the hedonic model. We constructed several different combinations of current and historical water clarity. The first is an interaction between historical and current water clarity (CMIN * HMIN). These two variables are entered as an interaction for two reasons. First, individuals' perceptions of current water clarity may be conditional on historical water clarity. Second, these two

variables are highly correlated. This interaction variable avoids the limitation for policy that occurs when historical water clarity is used solely, but still contains the very restrictive assumption that two lakes showing opposite trends in water clarity can have the same average water clarity.

To separate the direction of the change in water clarity in another model, the interaction term is made negative for a degrading lake and positive for an improving lake (CMIN * HMIN±). This variable differentiates between increasing and decreasing trends in water clarity, but still forces symmetry of implicit prices for lakes with the same absolute value of increasing and decreasing trends.

Another method of incorporating both the current and historical water clarity is to include a trend variable, constructed by subtracting the historical water clarity (HMIN) from the current minimum clarity (CMIN). The trend variable is included as a separate

variable in the same model with the current water clarity. The advantage of this specification, over a specification using only CMIN * HMIN±, is that CMIN–HMIN reflects the absolute magnitude of the difference between current and historical water clarity. However, symmetry is still assumed for increasing and decreasing trends.

Another model with multiple water clarity variables includes dummy variables representing the direction of the difference between current and historical water clarity. HMIN+ is 1 if the lake is improving in water clarity, and 0 if the lake has not changed or is degrading. HMIN- is 1 if the lake is de-

grading, and 0 if it has not changed or is improving. These two dummy variables, while not modeling the absolute difference between current and historical water clarity, do remove the implicit assumption of symmetry for increasing and decreasing trends.

Seasonal changes in water clarity. Survey respondents also noticed or inquired about how the lake's water clarity changes over the summer months. Public perception of lake water clarity may be based more on seasonal changes in clarity rather than on absolute clarity (Smeltzer and Heiskary 1990). Therefore, we constructed two variables that reflect the seasonal change in clarity, a ratio of max-

TABLE 4
MARGINAL PRICE CALCULATIONS

Water-Clarity Variable Functional Specification	Partial Effect of Water Clarity on Price	Marginal Price
CMIN ⇒ ln(CMIN)[a]	$\frac{\partial PRICE}{\partial CMIN}$	$\frac{\beta}{CMIN}$
PMIN ⇒ ln(PMIN)[b]	$\frac{\partial PRICE}{\partial PMIN}$	$\frac{\beta}{PMIN}$
HMIN ⇒ ln(HMIN)[c]	$\frac{\partial PRICE}{\partial HMIN}$	$\frac{\beta}{HMIN}$
CMIN*HMIN ⇒ ln(CMIN) * ln(HMIN)	$\frac{\partial PRICE}{\partial CMIN}$	$\frac{\beta \ln(HMIN)}{CMIN}$
CMIN * HMIN ± ⇒ln(CMIN) * ± ln(HMIN)	$\frac{\partial PRICE}{\partial CMIN}$	$\frac{\beta \ln(HMIN)}{CMIN}$
CMAX/CMIN ⇒ ln(CMAX)/ ln(CMIN)[d]	$\frac{\partial PRICE}{\partial CMIN}$	$\frac{-\beta \, (\ln CMAX)}{(\ln CMIN)^2 \, (CMIN)}$
CMAX/CMIN% ⇒ [ln(CMAX) – ln(CMIN)]/ ln(CMAX)	$\frac{\partial PRICE}{\partial CMIN}$	$\frac{-\beta}{(CMIN) \, (\ln CMAX)}$
CMIN ⇒ ln(CMIN) and CMIN-HMIN	$\frac{\partial PRICE}{\partial CMIN}$	$\frac{\beta}{CMIN}$
CMIN ⇒ ln (CMIN) and HMIN+ and HMIN–	$\frac{\partial PRICE}{\partial CMIN}$	$\frac{\beta}{CMIN}$

[a] CMIN represents the minimum clarity measurement for the year the property was sold.
[b] PMIN represents the minimum clarity measurement for the year previous to the sale.
[c] HMIN represents the average of the minimum clarity measurements for ten years previous to the sale.
[d] CMAX represents the maximum clarity measurement for the year the property was sold.
Note: Dependent = purchase price of property (price)

imum clarity to minimum clarity (CMAX/ CMIN) and the percentage change in clarity from the maximum clarity measurement (CMAX/CMIN%). These variables allow the effect of changes in the minimum clarity measurement to be derived based on its distance from the maximum clarity level. Unfortunately, these variables are subject to the limitation that different changes can have the same ratio (e.g., changes in clarity from six to three meters and two to one meters both result in a ratio of 2).

The variables presented here do not represent an exhaustive list of the different ways the water clarity variable may be constructed using secchi-disk measurements. Rather, they present a sampling of alternatives that can be used to investigate whether different ways of modeling a single environmental variable affects estimates of implicit prices. Differences are identified two ways: 1) significance or insignificance of coefficient estimates; and 2) differences in absolute magnitudes of computed implicit prices. The calculations of implicit prices are presented in Table 4. No statistical tests of specifications are conducted because all estimates are developed using the same data and each specification simply investigates a different measurement of water clarity in the equations.

V. DATA

Two issues were considered when choosing the time frame for property sales to include in the sample. First, the time period needed to be long enough to produce a sufficient number of observations to estimate a model and also provide a representative sample of property sales. The second consideration was the housing market conditions in Maine. The Maine housing market during the 1980s was very erratic, with large jumps in property prices from year to year. In the early 1990s, the housing market leveled out, showing very little change in house prices from year to year (Table 5). Large changes in the market may prevent equilibrium in the housing market. The assumption that any housing market is in equilibrium is often contestable, but in the case of a rapidly changing market,

TABLE 5
AVERAGE SELLING PRICE FOR A HOUSE IN MAINE

Year of Sale	Average Selling Price of Maine Property[a] (in dollars)
7/88–6/89	95,888
7/89–6/90	100,891
7/90–6/91	97,756
7/91–6/92	97,934
7/92–6/93	99,445
7/93–6/94	98,584

[a] These prices include both rural and urban residential property sales calculated from the Real Estate Transfer Tax base maintained by the Institute for Real Estate Research and Education, University of Southern Maine.

equilibrium cannot be assumed. Based on the housing market conditions in Maine, sales data were collected for the period January 1990 to June 1994. A four-year time frame was used because there are not a large number of sales in any one year.

Data on lakefront property sales were collected from transfer tax records, available at town offices, for all arms-length transactions that occurred in the four-year time frame. The 22 lakes in the sample encompassed 39 organized towns and unorganized territories. Once the property sales were identified, information about the structural characteristics of the properties was recorded from the property tax records.

The final sample consisted of residential or recreational single-family homes or unimproved land with shore frontage on the lake (Table 6). Multi-unit properties and condominiums were not included in the sample because the land is common among the property owners, so the value of the land would not be equivalent to single-family homes. In addition, tracts of land larger than 20 acres were excluded from the sample. The majority of these large tracts of land are agricultural. These property owners may have different tastes and preferences for water clarity than lake residents because water clarity does not affect agricultural production and, consequently, the value of the property. Because there were not enough sales of this type to estimate a separate model for this group, they were eliminated from the analysis. Estima-

TABLE 6

SELECTED SUMMARY STATISTICS FOR THE FINAL PROPERTY DATA SET

	Group 1	Group 2	Group 3
PRICE	$96,304	$80,591	$35,160
average property price	(65253)[a]	(55942)	(26695)
LOTSZ	1.02 ac	1.37 ac	0.81 ac
acres	(1.84)	(2.35)	(0.79)
FRONT	130.7 ft	142.9 ft	145.3 ft
feet front on lake	(97.6)	(108.6)	(91.8)
CMIN	5.66 m	4.03 m	2.82 m
average minimum secchi	(3.02)	(1.83)	(0.87)
PMIN	5.43 m	4.09 m	2.89 m
average minimum secchi	(3.20)	(1.83)	(0.89)
HMIN	5.34 m	4.24 m	3.09 m
10 year average minimum	(2.94)	(1.66)	(0.65)
CMAX	7.89 m	6.23 m	4.80 m
av. max. secchi	(3.50)	(1.09)	(0.77)
N	89	295	147

Note: Prices were inflated to 1995 dollars using the CPI.
[a] Standard errors are shown in parentheses.

tion resulted in the loss of a few observations because of missing data: one from Lewiston/Auburn, three cases for Augusta/Waterville, and eight for Northern Maine. In addition, eight properties were eliminated from Augusta/Waterville because they were highly unrepresentative of properties found in the group. This assessment was based on a site visit. The data for each lake group were also screened for outliers, using Mahalanobis' distance and Cook's distance (Belsley, Kuh, and Welsch 1980). Two observations were removed from Augusta/Waterville based on this screening (see Table 6 for the total number of observations by group used to produce the final estimates).

VI. RESULTS

The estimation results reveal that nearly all of the water clarity variables were significant and of the expected sign for each market group; the exceptions being CMIN * HMIN± and CMIN/CMAX, which in most cases produced insignificant coefficients. The estimation results for the water clarity variables are presented in Table 7 and Figures 1 through 3. We will discuss the results of the models based on the effect of the market groupings on implicit prices, and the differ-

ences in the implicit prices for water clarity between models within a market group.

We estimated the nine models for the three separate market groups and found that implicit prices varied between markets. The Augusta/Waterville group showed the smallest price for water clarity for each of the water clarity variables we estimated. The Lewiston/Auburn and Northern Maine groups produced implicit prices within the same range (overlapping confidence intervals), but quite different when considered as a portion of the average house price. For example, for the variable PMIN, the implicit prices are $5,061 for Lewiston/Auburn and $8,084 for Northern Maine. However, as a percentage of the average house price in Northern Maine, the price for water clarity was 23% of the house price, whereas in Lewiston/Auburn it was 5%. These results suggest that identification of market groups would provide better estimates of implicit prices when large geographic areas are to be included in the analysis. Similarly, if point estimates from the analysis are to be applied to different geographic regions, estimates should be developed for individual markets within the region.

Within each of the market groups, the different water clarity variables did not produce

TABLE 7

ESTIMATION RESULTS FOR THE WATER CLARITY VARIABLES

		Group 1	Group 2	Group 3
CMIN	Coeff.	39774***	7553.6**	17265**
	SE	(9869.2)	(4330.7)	(7534.6)
	Implicit Price[a]	$7,027	$1,874	$6,122
PMIN	Coeff.	27479***	8342.0**	23363***
	SE	(6781.3)	(4530.8)	(6763.8)
	Implicit Price	$5,061	$2,040	$8,084
HMIN	Coeff.	36215***	11197**	32228**
	SE	(8473.0)	(5849.0)	(15352)
	Implicit Price	$6,795	$2,641	$10,430
CMIN * HMIN	Coeff.	22179***	4448.3**	13449***
	SE	(5469.5)	(2448.8)	(5003.2)
	Implicit Price	$5,447	$1,479	$5,246
CMIN * HMIN±	Coeff.	−3572.6**	853.42	−1704.5
	SE	(2063.7)	(1024.4)	(1392.9)
	Implicit Price	−$877	$284	$665
CMIN/CMAX	Coeff.	−5645.9***	−401.99	−4649.8
	SE	(1508.2)	(887.86)	(4110.6)
	Implicit Price	$860	$117	$2,625
CMIN/CMAX%	Coeff.	−86050***	−15402**	−29925**
	SE	(19864)	(8470.0)	(13946)
	Implicit Price	$7,837	$2,112	$6,802
CMIN	Coeff.	43607***	9218.9**	20723
	SE	(9838.3)	(5132.0)	(17352)
	Implicit Price	$7,704	$2,288	$7,349
CMIN-HMIN	Coeff.	−24526**	−2055.1	−1664.8
	SE	(12071)	(3388.5)	(7517.2)
CMIN	Coeff.	31307***	7937.6**	14101
	SE	(12091)	(4837.7)	(11324)
	Implicit Price	$5,531	$1,970	$5,000
HMIN+	Coeff.	9113.2	−5598.3	8668.5*
	SE	(11430)	(6925.9)	(6067.4)
HMIN−	Coeff.	48202***	−4300.5	5004.4
	SE	(16863)	(5725.2)	(4654.0)

Note: Dependent = Price
[a] one−tailed test
* significant to the 90th percentile; ** significant to the 95th percentile; *** significant to the 99th percentile.

substantially different implicit prices; the confidence intervals overlap.[4] However, there is a large enough difference between the prices for water clarity that if used as a point estimate in a benefits-cost analysis, these estimates could produce different policy recommendations. For example, in the Northern Maine model, implicit prices range from $5,246 (CMIN * HMIN) to $10,430 (HMIN) for the models that produced significant water clarity variables. Although these are probably not significantly different—the confidence intervals overlap—if used as a point

estimate, the model using historical water clarity shows twice the effect on price as the model using the interaction variable. By modeling the effect of water clarity on house prices using only the interaction variable, policy makers may come to a different conclusion than if they had used a historical measure of water clarity.

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[4] One reviewer has clearly noted, Bayesian diagnostic techniques allow stronger inferences to be drawn from this data (Atkinson and Crocker 1987; Graves et al. 1988).

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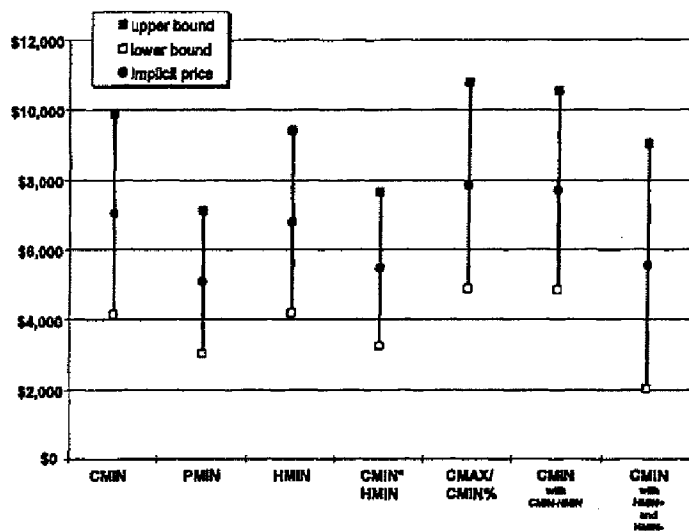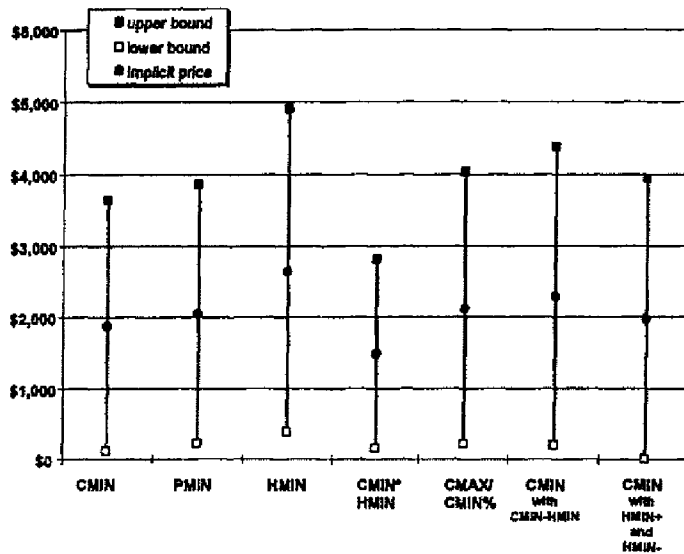

FIGURE 1
CONFIDENCE INTERVALS FOR IMPLICIT PRICES FOR WATER CLARITY: LEWISTON/AUBURN

FIGURE 2
CONFIDENCE INTERVALS FOR IMPLICIT PRICES FOR WATER CLARITY: AUGUSTA/WATERVILLE
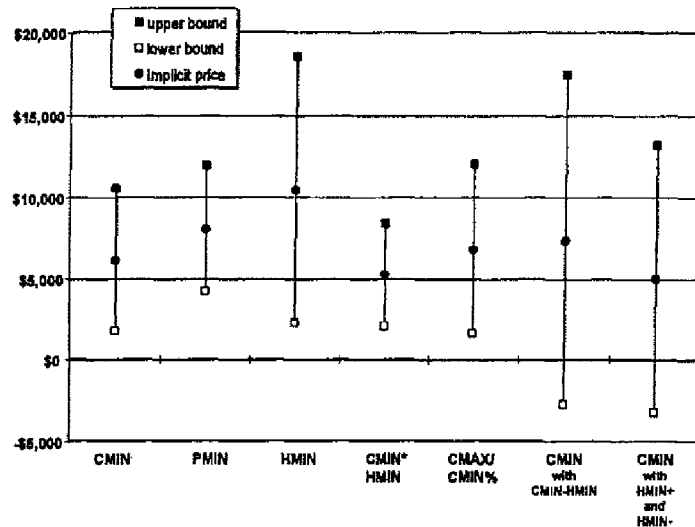
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FIGURE 3
CONFIDENCE INTERVALS FOR IMPLICIT PRICES FOR WATER CLARITY: NORTHERN MAINE

VII. CONCLUSION

This study provides evidence that the measurement of an environmental-quality variable, such as water clarity, affects the implicit prices derived from hedonic equations. A number of different measurements of water clarity, based on different assumptions about perceptions of water clarity, are significantly related to property price. These estimates produced a broad range of implicit prices for water clarity. Consequently, selection of a measure of environmental quality to enter into a hedonic equation should not be based solely on the convenience of available environmental data. Widely different point estimates may be generated for assessing the benefits to property owners of improving environmental quality, which could result in radically different policy decisions. Instead, the selected measure of the environmental variable should be based on conceptually and theoretically sound logic and should reflect the public's perceptions of environmental quality. The results of the current analysis provide mixed findings with no clear evidence that one measure of water clarity is clearly superior to the others considered. These mixed findings reinforce the need for caution when selecting one measure of environmental quality to include in the hedonic-price equations. It may be the case, as we have found, that all property owners do not perceive water quality in the same way. However, including individual perceptions in the model is often difficult, and may preclude clear translation of the results for policy purposes. In conclusion, just as validation work is needed with other nonmarket-valuation methods, similar research is warranted here if first-stage hedonic-price equations are to be used to derive point estimates for measuring the effect of environmental quality on property prices.

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